Technical Report 1157

Personnel Turnover and Team Performance

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14. ABSTRACT *(Maximum 200 words)*: This project was designed to provide information about personnel turnover in work teams. Two tasks (production, decision making) and two methodologies (laboratory experimentation, computer simulation) were employed. Experimental studies using the production task investigated how newcomers affect a team's transactive memory system -- a shared mental model about how task competencies are distributed across members. Experimental studies using the decision-making task investigated conditions under which newcomers can produce innovation by altering the team's task strategy. Simulation studies extended the laboratory work in various ways (e.g., by investigating turnover effects in larger social units and over longer time periods). Results indicated that providing team members with information about a newcomer's skills prior to turnover eliminated the negative impact of turnover on both transactive memory and team performance. Newcomers who sought to change the team's task strategy were more effective when the team was assigned (rather than chose) its initial strategy and failed (rather than succeeded) prior to newcomers' arrival. Simulation studies showed, among other things, that the value of transactive memory varies as a function of group size and task difficulty. This project demonstrates the utility of multi-method research on personnel turnover and suggests a number of questions for future research.

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FOREWORD

Personnel turnover, a fact of life in the Army, can have several consequences. For example, when membership change is planned and new personnel are well-trained, turnover may have minimal effects on team performance. In contrast, when membership change is unplanned and/or new personnel are not prepared for their mission, turnover may severely degrade team performance. This report suggests several strategies for reducing the costs and enhancing the benefits of membership change in teams. It also documents the synergies that can result when investigators from different disciplines (social psychology, sociology, and computer science) use different methodologies (laboratory research and computer simulation) to examine a common problem. For example, in addition to providing information about the conditions under which newcomers can influence existing work practices in teams, the simulation studies in this report suggest how turnover might be used to destabilize "enemy" groups, which is highly relevant to counter-terrorism situations faced by today's Army.

Michelle Sams

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Technical Director

PERSONNEL TURNOVER AND TEAM PERFORMANCE

EXECUTIVE SUMMARY

Research Requirement:

Personnel turnover can profoundly influence team performance, because it alters both the distribution of knowledge and skills in the team and the relations among team members. When current members leave, those who remain must renegotiate their responsibilities for storing, sharing, and utilizing knowledge. When new members enter, they must acquire information about their role and current members' competencies and responsibilities. Although turnover often harms team performance, it is sometimes beneficial (e.g., when high-skilled newcomers enter). This project was designed to clarify how turnover affects teams' transactive memory systems and newcomers' ability to serve as change agents.

Procedure:

Two team tasks (production and decision making) and two methodologies (laboratory experimentation and computer simulation) were employed. Three related lines of work were conducted. Studies using the experimental version of the production task investigated how newcomers affect the team's transactive memory system -- a shared mental model about how task competencies are distributed across team members. Studies using the experimental version of the decision-making task investigated the conditions under which newcomers stimulate teams to alter their task strategies. Simulation studies extended the laboratory work in various ways, for example by investigating turnover effects in larger social units and over longer time periods.

Findings:

When no information was provided about a newcomer's task-relevant skills, turnover damaged the team's transactive memory system and led to lower performance. When such information was provided, both transactive memory and team performance were as high following turnover as no turnover. Newcomers were more effective in changing the team's task strategy when the team was assigned (rather than chose) its initial strategy and failed (rather than succeeded) prior to the newcomer's arrival. Simulation studies showed, among other things, that the value of transactive memory varies as a function of group size and task difficulty.

Utilization of Findings:

This project demonstrates the utility of multi-method research on personnel turnover, provides information about transactive memory and newcomer innovation, and suggests a number of questions for future research. In addition, our simulation work is potentially useful for counter-

terrorism studies (e.g., examining strategies for stabilizing and destabilizing groups). Findings suggest that for battalions and smaller units, when new personnel are rotated in, current unit members should be pre-briefed on newcomers' skills, training, and experience. Units that are enabled to act autonomously and define for themselves how to carry out their mission will be less receptive to changes suggested by new personnel than will units in which commanders define the mission. Hence, newcomers will have less impact in special forces than in regular forces. For battalions in particular, transactive memory is a force multiplier and facilitates rapid and accurate decision making. Hence, such units should train together, and technology that retains transactive memory for the unit, such as databases containing information about who knows what, will facilitate performance.

PERSONNEL TURNOVER AND TEAM PERFORMANCE

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Collaborative work is an increasingly important aspect of organizational life, and many organizations assign their most critical tasks to small groups, such as task forces, quality circles, and work teams (Hackman, 1990; Ilgen, 1999; Sundstrom, 1999). This is not surprising, because there are several plausible reasons to believe that teams should be more effective and efficient than individual workers. Not only do teams typically possess more task-relevant skills and knowledge than do individuals, but team members can also share these resources, redistribute responsibilities to meet new task demands, and motivate one another to work hard. Unfortunately, however, there is evidence that teams do not always provide the benefits they promise. Research in laboratory settings shows that teams often fail to realize their potential productivity because of coordination and motivation problems (Steiner, 1972). And research in organizational settings suggests that successful work teams may be the exception rather than the rule (Hackman, 1990, 1998).

Work teams are small groups of a special kind (Salas, Dickinson, Converse, & Tannenbaum, 1992). Team members share common task goals and are interdependent for achieving these goals, which in turn necessitates information exchange and response coordination. Moreover, team members are typically differentiated in terms of their roles and responsibilities and remain on the team for a limited amount of time. Because teams are a subcategory of small groups, they have the same basic tasks that all groups have. These tasks include regulating the number and type of people who belong to the group; maintaining and sometimes altering the group's status system, roles, and norms; reducing tensions arising from opinion controversy and competition for scarce resources; managing the group's physical and social environment; and facilitating group decision making and productivity (Levine & Moreland, 1998). Each of these tasks is complex in its own right, and solutions to one task can have important implications for others (e.g., changes in a group's composition can affect its performance). It follows, then, that teams face many challenges in attaining and maintaining proficiency, which explains why their actual productivity often falls below their potential productivity.

Researchers are actively seeking to understand and improve team effectiveness in a variety of organizational settings (for example, see Guzzo, Salas, & Associates, 1995; Salas, Bowers, & Eden, 2001; Salas & Fiore, 2004; Turner, 2001). In this context, military teams are receiving substantial research attention (e.g., Andrews, Waag, & Bell, 1992; Cannon-Bowers & Salas, 1998; Dwyer, Fowlkes, Oser, Salas, & Lane, 1997; Salas, Bowers, & Cannon-Bowers, 1995). Research on teams is timely not only because organizational managers want help in designing effective work units, but also because many exciting theoretical questions remain to be answered concerning collaborative work in teams.

Temporal Aspects of Team Life: Personnel Turnover

Teams are not static entities, but instead change in dynamic ways over time. In order to clarify the determinants of team performance, it is therefore necessary to consider temporal aspects of team life, which include team formation and dissolution; team development (i.e., changes in the team as a whole); team socialization (i.e., changes in the relationship between the team and each of its members); temporal aspects of team task performance (e.g., action synchronization, activity scheduling); team learning under stable conditions; and team adaptation to unstable conditions, such as changing membership (Arrow, McGrath, & Berdahl, 2000; Levine & Moreland, 1994; McGrath & O'Connor, 1996). Our primary interest is how teams respond to membership change, or personnel turnover, which occurs when new members enter an existing team and/or a subset of current members exits the team.

Personnel turnover is one of the most daunting challenges that teams face. Turnover represents a change in team composition that can have profound consequences for team performance, because it alters both the distribution of knowledge within the team (the knowledge network) and the relations among team members (the social network). When current members leave, those who remain must renegotiate their responsibilities for storing and sharing information. When new members enter, they must acquire knowledge about their roles and about others= competencies and responsibilities. It is important to recognize that the consequences of turnover can be positive as well as negative. For example, when a team is performing poorly and newcomers possess useful task knowledge, they may suggest changes that enhance team adaptability.

Although turnover is inevitable in all teams that exist over time, it is more common in some situations than others. For example, teams operating in dangerous environments (e.g., combat infantry squads) typically lose members at a faster rate than do teams operating in safer environments and hence must develop more sophisticated techniques for handling turnover. Broad societal trends can also influence the prevalence of turnover. For example, American businesses are currently experiencing high rates of turnover because corporate downsizing, outsourcing, and mergers have greatly increased worker mobility. Although this mobility may not last forever, it is widely expected that work teams in business organizations will have to cope with high levels of turnover for the foreseeable future. How to deal productively with turnover is thus a critical question for organizations of various kinds (Peterson & Mannix, 2003).

Background

A number of studies examining the effects of turnover in groups and organizations have been conducted. In the following discussion, we focus primarily on small group research, mentioning organizational research where appropriate.

One method of studying membership change in groups involves gradually replacing old members with new members. This "generational" paradigm has been used to investigate such diverse phenomena as norm persistence, leadership, and group performance (Kenny, Hallmark, & Sullivan, 1993). It has been found that norms persist over several generations, during which old members gradually leave the group and new ones join (Jacobs & Campbell, 1961), and that more arbitrary norms decay faster than less arbitrary ones (MacNeil & Sherif, 1976). Other generational studies have shown that, over time, groups develop leadership systems based on seniority and become more proficient in carrying out their tasks (Insko, Gilmore, Moehle, Lipsitz, Drenan, & Thibaut, 1982; Insko, Thibaut, Moehle, Wilson, Diamond, Gilmore, Solomon, & Lipsitz, 1980).

Studies of membership change using other paradigms have demonstrated that change sometimes facilitates group and organizational performance. For example, Arrow and McGrath (1993) found that student groups meeting over a semester wrote better essays when they experienced membership change than when they did not. In addition, Ziller, Behringer, and Goodchilds (1962) discovered that groups with changing memberships were more creative than groups with stable memberships. Moreover, Rogelberg, Barnes-Farrell, and Lowe (1992) found that "stepladder" groups, in which a dyad that had worked together was joined by a third and then a fourth member, produced higher quality decisions than did conventional four-person groups, in which all members worked together from the beginning. Finally, there is evidence that turnover can have beneficial effects on performance in organizational settings (e.g., Virany, Tushman, & Romanelli, 1992).

The notion that membership change enhances group performance is consistent with research on the effects of member diversity and member transfer. In regard to member diversity, evidence suggests that heterogeneous groups, in which members differ on such dimensions as demographic characteristics, abilities, and educational and functional backgrounds, are often more creative than homogeneous groups (Argote & Kane, 2003). Though diversity does not always improve group performance (Milliken, Bartel, & Kurtzberg, 2003; Moreland, Levine, & Wingert, 1996), to the extent that membership change increases diversity *and* creativity facilitates performance, membership change should be beneficial. In regard to member transfer, evidence indicates that moving members from one group to another is often, though not always (e.g., Gruenfeld, Martorana, & Fan, 2000), an effective way of transferring knowledge within and between organizations (Argote & Kane, 2003). Because the infusion of new knowledge frequently improves group performance, research on member transfer suggests that membership change can have productive consequences.

However, turnover does not always enhance group and organizational performance (e.g., Goodman & Leyden, 1991; Moreland, Argote, & Krishnan, 1998). This is because, in order for turnover to have positive effects, it must outweigh the substantial benefits that group members derive from working together (Argote & Kane, 2003). Such experience makes it easier for members to recognize one another's strengths and weaknesses, to anticipate one another's actions, and to develop efficient transactive memory systems. In addition, it improves members' motivation and ability to share information and their willingness to express disagreement. Although "too much" experience working together can harm group members' performance (e.g., Katz, 1982; Kim, 1997), there is little doubt that at least a modicum of shared experience is necessary for good collective performance. If so, then the appropriate question becomes not whether membership change is inherently better or worse than stability, but rather what conditions increase and decrease the value of such change (cf. Abelson & Baysinger, 1984).

Several factors have been shown to affect the impact of turnover on group and organizational performance. One such factor is the time course of membership change. Trow (1960) found that while a group's overall level of turnover did not systematically affect its performance, increases in the rate of turnover harmed performance. Curvilinear relationships between turnover and performance have also been obtained, both at the small group (Glaser & Klaus, 1966) and organizational (Argote, Epple, Rao, & Murphy, 1997) levels. Another factor that can influence the impact of turnover is member ability. Trow (1960) and Naylor and Briggs (1965) found that groups performed better when new members were superior to the people they replaced (i.e., more intelligent or skilled) than when they were inferior (see also Argote et al., 1997).

Additional determinants of turnover effects include the way in which members interact with one another, the structure of the group, and the complexity of the task. For example, turnover causes more problems when group members work interactively rather than independently (Naylor & Briggs, 1965) and when the group has low rather than high structure (Carley, 1992; Devadas & Argote, 1995). Regarding task complexity, turnover is more problematical when the task is routine rather than challenging (Argote, Insko, Yovetich, & Romero, 1995), presumably because task knowledge changes more slowly for routine than for challenging tasks, and hence the departure of experienced members is more costly in the former case. It is also worth noting that the effects of turnover on performance can be rather subtle. For example, even when turnover does not directly affect group performance, it can undermine a leader's effectiveness in weighting subordinates' judgments (Hollenbeck, Ilgen, Sego, Hedlund, Major, & Phillips, 1995).

The conditions under which turnover has positive versus negative effects on group performance have been addressed by McGrath and his colleagues (e.g., Arrow & McGrath, 1993, 1995; McGrath & O'Connor, 1996). They argued that the nature and impact of membership change depend on such factors as the kind of group involved, its status and role systems, and the particular members involved. They predicted, for example, that change will have fewer consequences when peripheral rather than central members are involved. McGrath and his colleagues also emphasized the importance of the magnitude and direction of membership change (e.g., addition vs. subtraction of members), hypothesizing, for example, that the effects of change increase with the number of members who participate in it. Finally, they discussed the impact of the temporal patterning of membership change (e.g., frequency, regularity, predictability), predicting, for example, that groups with a history of repeated and predictable change will develop procedures for managing the disruptive effects of turnover.

The Role of Shared Cognition

We assume that turnover affects team performance to the extent that it influences (a) the amount, quality, and distribution of task- and team-relevant knowledge, skills, and attitudes within the team (cf. Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995) and (b) team members' ability to coordinate their actions in the service of attaining collective goals. In recent years, there has been increasing interest in the knowledge component of team effectiveness, particularly in the role that *shared cognition* plays (Salas & Cannon-Bowers, 2001). Shared cognition is often conceptualized in terms of shared mental models, which are assumed to influence team performance through their impact on members' ability to engage in coordinated actions (Fiore, Salas, & Cannon-Bowers, 2001). Shared mental models involve knowledge about the team's task, individual members' responsibilities, and potential situations the team may encounter. Interest in shared cognition in general and shared mental models in particular has been stimulated by two major developments. The first is increased awareness of the fact that human cognition is an interpersonal, as well as an intrapersonal, phenomenon (e.g., Levine, Resnick, & Higgins, 1993; Nye & Brower, 1996; Resnick, Levine, & Teasley, 1991). The second is increased desire to understand and enhance team performance (e.g., Levine & Choi, 2004; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). Though shared cognition is currently eliciting a good deal of theoretical and empirical attention (e.g., Levine & Higgins, 2001; Salas & Cannon-Bowers, 2001; Tindale, Meisenhelder, Dykema-Engblade, & Hogg, 2001), many questions remain about how it should be defined and measured, what factors affect its development, and when it is most likely to influence team performance (e.g., Cannon-Bowers & Salas, 2001; Kraiger & Wenzel, 1997; Mohammed & Dumville, 2001; Rentsch & Klimoski, 2001).

Although, as Cannon-Bowers and Salas (2001) noted, the term "shared cognition" can have multiple meanings, it is typically measured by calculating the level of agreement between team members' mental representations of some relevant issue, such as task requirements, team process, or member expertise, with the assumption that higher agreement indicates more shared cognition (e.g., Levesque, Wilson, & Wholey, 2001; Mathieu et al., 2000; Stout et al., 1999). Though useful for many purposes, such indices have two potential problems. If obtained after task performance, they may reflect the kinds of memory distortions associated with most retrospective measures. If obtained during task performance, they may force team members to reflect on their mental activities at times and in ways that are "unnatural," thereby providing misleading information about the cognitions that typically accompany joint work. An alternative approach involves assessing team members' behaviors as they work together and then using these behaviors as markers, or indices, of their shared cognition (cf. Moreland, 1999; Weick & Roberts, 1993). This approach is consistent with the argument that, in many situations, it is neither possible nor conceptually useful to separate social interaction and cognition. In such cases, rather than being the cause or consequence of cognition, interaction *constitutes* cognition (Levine et al., 1993).

Team members may have shared cognition prior to interacting with one another, because of experience on other teams (Rentsch & Klimoski, 2001) or preprocess coordination (Fiore et al., 2001; Wittenbaum, Vaughan, & Stasser, 1998). However, such cognition frequently develops as a result of collaborative work. Of the various kinds of shared cognition that can develop in teams, transactive memory systems are particularly important. Such systems, which arise through communication and interaction among team members, combine the knowledge possessed by individual members with the shared knowledge of who knows what within the team. Because transactive memory systems are based on team members' familiarity with one another's task-relevant knowledge, any factor that weakens this familiarity (e.g., the entry and/or exit of members) would be expected to degrade the team's transactive memory system and thereby its performance.

Communication and interaction among team members can also affect shared cognition in other ways. For example, new members entering a team sometimes suggest changes in how the team performs its task. These suggestions, which constitute challenges to the team's existing shared cognition, are often rejected out of hand. Under some conditions, however, they may be considered and adopted. When this occurs, the newcomer produces changes in the team's shared cognition about how to perform its task, which in turn produce alterations in members' task-relevant behaviors. In cases where the team is performing poorly prior to the newcomer's entry, the newcomer's challenge can serve a useful role in stimulating innovation.

Research Agenda

Our research program utilized two team tasks (production and decision making) and employed two methodologies (laboratory experimentation and computer simulation). Three related lines of work were conducted. Studies using the experimental version of the production task investigated how newcomers affect the team's transactive memory system -- a shared mental model about how task competencies are distributed across team members. Studies using the experimental version of the decision-making task investigated the conditions under which newcomers stimulate adaptation and innovation in work teams. The simulation studies, which employed powerful computer programs that have proven useful in modeling group and organizational performance, extended the laboratory work in various ways, for example by investigating the impact of turnover in larger social units and over longer time periods.

Transactive Memory

An important trend in social and organizational psychology is the growing awareness that group members can collaborate in the processing of information (see Argote, Gruenfeld, & Naquin, 2000; Hinsz, Tindale, & Volrath, 1997; Larson & Christensen, 1993). One example of this trend is work on transactive memory (see Hollingshead, 1998; Moreland, 1999; Wegner, 1987; 1995).

Wegner (1987) was among the first to analyze transactive memory. Wegner noted that many people supplement their own memories, which are limited and unreliable, with various external aids. These aids include objects, such as address books, and other people, such as relatives and coworkers. Wegner was intrigued by the use of people as memory aids. He believed that transactive memory systems develop in many kinds of groups (from couples to work groups to organizations) to ensure that important information is not forgotten. Transactive memory systems combine the knowledge of individual group members with a shared awareness of who knows what. When group members need information, but cannot remember it on their own or are not sure that their own memories are accurate, they can thus rely on one another for help. In this way, transactive memory systems give group members access to more information than any one person could remember alone.

Our research has focused on work groups. The potential benefits of transactive memory systems for such groups are clear. When workers know more about each other, they can plan more sensibly, assigning tasks to the people who will perform them best. Coordination should improve as well, because workers can anticipate one another's behavior, rather than just reacting to it (Murnighan & Conlon, 1991; Wittenbaum et al., 1998). Finally, any problems should be solved more quickly and easily by workers who know more about one another, because then they can match problems with the people who are most likely to solve them (Moreland & Levine, 1992). Once those people are identified, they can be asked for help, or the problems can simply be given to them to solve.

Indirect evidence for the beneficial effects of transactive memory on work group performance can be found in research on familiarity among work group members and the recognition of expertise in decision-making teams. In the first research area, a common finding is that groups perform better when their members have had more experience working together (e.g., Berman, Down, & Hill, 2002; Goodman & Shah, 1992; Kanki & Foushee, 1989; Murnighan & Conlon, 1991; Watson, Kumar, & Michaelsen, 1993). And in the second research area, a common finding is that groups make wiser decisions when they can identify which member has the most expertise on an issue (e.g., Henry, 1993; 1995; Henry, Strickland, Yorges, & Ladd, 1996; Littlepage, Robison, & Reddington, 1997; Littlepage, Schmidt, Whisler, & Frost, 1995; Littlepage & Silbiger, 1992). Both of these findings are consistent with the claim that group performance is better when transactive memory systems are stronger. It should be noted, however, that transactive memory was not measured in any of the studies just cited, so its exact role in group performance is unclear.

Over the past few years, we have carried out a series of laboratory experiments designed to provide more direct evidence about how transactive memory systems affect the performance of work groups (see Liang, Moreland, & Argote, 1995; Moreland, 1999; Moreland & Myaskovsky, 2000). In our research, transactive memory systems are usually created through shared experience. We manipulate experience by training group members in different ways. Everyone learns to perform a rather complex task -- building a transistor radio from a kit containing dozens of parts. Although treatment conditions vary from one experiment to another, we often train the participants in one condition individually, while the participants in another condition are trained together, in three-person groups. The latter condition provides shared experience, which allows group members to develop a transactive memory system by learning who knows what.

The content of training is the same for all participants, regardless of treatment condition. At the training session, which lasts for about an hour, the experimenter first demonstrates how to build the radio, answering any questions that participants may have as he or she works. Then, the participants are asked to build a radio themselves. In the individual training condition, each person builds his or her own radio. In the group training condition, group members build a single radio together. The experimenter answers any questions participants may have while they work on the radios, and once they are done, he/she inspects the radios and offers detailed feedback on any mistakes that were made.

A week later, a second session is held, again lasting for about an hour. At that session, all of the participants are tested in groups to evaluate how well they learned to build the radios. In the individual training condition, each group contains three people who were trained separately and thus are strangers to each other. In the group training condition, each group contains the three people who were trained together the week before. We first ask the members of each group to recall, working together as a group, as much as they can about building radios and then to record that information on a blank sheet of paper. Next, we ask each group to build a radio, working within a time limit and without help from the experimenter. Cash prizes are given to the groups that perform best by building radios more quickly and with fewer mistakes. Before the testing session ends, we often ask participants to complete a brief questionnaire that measures both thoughts and feelings about their teams.

Three measures of group performance are collected at the testing session. Procedural recall reflects how much a group could remember about building radios. Assembly errors reflect how many mistakes a group made while building its radio. Assembly time is how long it took a group to complete its radio. In most of our research, procedural recall correlates negatively with both assembly errors and assembly time, which correlate positively with one another. Transactive memory is measured by evaluating videotapes made of the groups while they work on radios during their testing sessions. Trained judges carefully examine group behavior for three signs that transactive memory systems are operating. The first of these is memory differentiation -- the tendency for group members to specialize at remembering different aspects of building a radio. There should be more memory differentiation in groups with stronger transactive memory systems. A second sign is task coordination – the ability of group members to work together smoothly on a radio. Groups with stronger transactive memory systems should show greater task coordination. Finally, the third sign is task credibility – the level of trust in a group about whether each person knows what he or she is doing while working on a radio. Task credibility should be higher in groups with stronger transactive memory systems. These three signs are always strongly (positively) correlated with one another, so to simplify data analyses, we usually create a single transactive memory index by simply averaging the relevant scores together.

What have our experiments shown? First, group training (shared experience) is indeed one way to create transactive memory systems. When group members are trained together, rather than apart, they behave differently while building their radios – levels of memory differentiation, task coordination, and task credibility, all signs of transactive memory, are significantly higher in such groups. Second, group performance is significantly better when the members of a group are trained together, rather than apart. Group training helps members to remember more about building radios and to make fewer mistakes in the radios that they build. These performance benefits can be large, sometimes as much as 40%. Third, statistical analyses and variations in treatment conditions both show that the performance benefits of group training are due entirely to transactive memory, not to other factors that might be associated with group training, such as (a) motivation; (b) group cohesion; (c) social identity; (d) group development; (e) generic learning about building radios in (any) groups; or (f) better communication about radio building. To put it differently, there seems to be nothing about group training, other than the creation of transactive memory systems, that causes group performance to improve.

Along the way, a few other findings that are worth noting have emerged from our research. First, turnover weakens transactive memory and thus harms the performance of groups whose members are trained together. Second, group training does not seem to produce social loafing (the tendency for most people to put less effort into tasks when they work in groups rather than alone). Some might argue that group training is risky because people are less likely to learn their tasks well. Yet when we tested people individually, rather than in groups, we found no difference in the performance of those who were given group vs. individual training. Finally, the behavioral signs of transactive memory that we look for in videotapes of group behavior are valid measures – they correlate strongly with other, more direct measures of who knows what (e.g., comparing group members' beliefs about one another's skills with their actual skills, then computing levels of belief accuracy and agreement within groups).

As organizations have become more dynamic, work groups have begun to experience more and more turnover. Turnover is problematic for transactive memory systems, because changes in group membership make it risky for people to rely on one another's knowledge. If somebody leaves a work group, and other members have relied on that individual for valuable knowledge, then access to that knowledge becomes much more difficult. At best, group members might try to stay in contact with the person who left, hoping that he/she would still be willing to assist them when necessary; learn whatever they need to know for themselves; ask for help from someone outside the group who has similar knowledge; or bring someone who has that knowledge into the group as a new member.

The negative impact of turnover on transactive memory in work groups was clear in one of our early experiments, where groups whose members were trained together were broken apart at the start of the testing session. The participants were surprised when we asked them to join new groups, each containing three persons who were all trained in groups, but not in the same groups. [The purpose of reassigning group members this way was to see if the benefits of group training were due to generic learning about building radios in groups. Our reasoning was that if such learning was why group training helps, then it should not matter if participants who were trained in groups remained in those groups.] The new groups showed few signs of transactive memory and performed poorly. In fact, they performed no better than groups whose members were trained individually. Of course, the turnover that we created in these groups was dramatic (all members of the original groups were removed) and unexpected. Maybe the negative effects of turnover changes are weaker when more group members are left in place and/or groups are warned to expect turnover.

Activities

Experiment 1. These considerations led to our first experiment under the ARI contract. There were 312 participants in that experiment, all college students at the University of Pittsburgh (196) or at Carnegie Mellon University (116). Most of the participants (270) were randomly assigned to 90 groups, each containing three unacquainted persons of the same sex. The other participants served as newcomers for the groups that experienced turnover.

In this experiment, the original members of each group were trained together. Some groups were warned before their training began that turnover would occur at the start of their testing sessions. They were told that one member of the group (not identified) would be removed and replaced by someone who was individually trained. Other groups did not receive this warning. The other factor in our design was whether turnover actually occurred at the start of the testing sessions. In some groups, one member (chosen at random) was indeed removed and replaced with a newcomer who had been trained individually. In other groups, this turnover did not occur. We expected to see stronger signs of transactive memory, and better group performance, when no turnover occurred, whether a warning was given or not. And when turnover did occur, we expected to see weaker signs of transactive memory, but better group performance, when a warning was given. Why? We reasoned that if group members expected turnover, but did not know who would be leaving or what that person's replacement might be like, they would be less motivated to develop a transactive memory system. Instead, each person might well try to learn as much as possible about the task on his or her own, without relying on others.

The results of the experiment were somewhat puzzling. We performed a series of multiple regression analyses, in which group scores on one of the performance measures (procedural recall, assembly errors, assembly time), or the transactive memory index (reflecting levels of memory differentiation, task coordination, and task credibility within groups), were regressed on whether turnover occurred, whether turnover was expected, and the interaction between those factors, along with such variables as group gender and which university group members attended. There were few significant ($p < .05$) findings, and they were difficult to interpret. For example, whether turnover occurred and whether it was expected interacted in the analysis of procedural recall (see top of Figure 1). When turnover did not occur, procedural recall was significantly higher when turnover was expected ($M = 26.13$) than when it was not ($M = 22.33$). But when turnover did occur, expectations had a surprising effect – procedural recall was significantly *lower* when turnover was expected ($M = 22.45$) than when it was not ($M = 25.70$). Put another way, in the latter case recall was affected positively by unexpected turnover, but negatively by turnover that was expected.

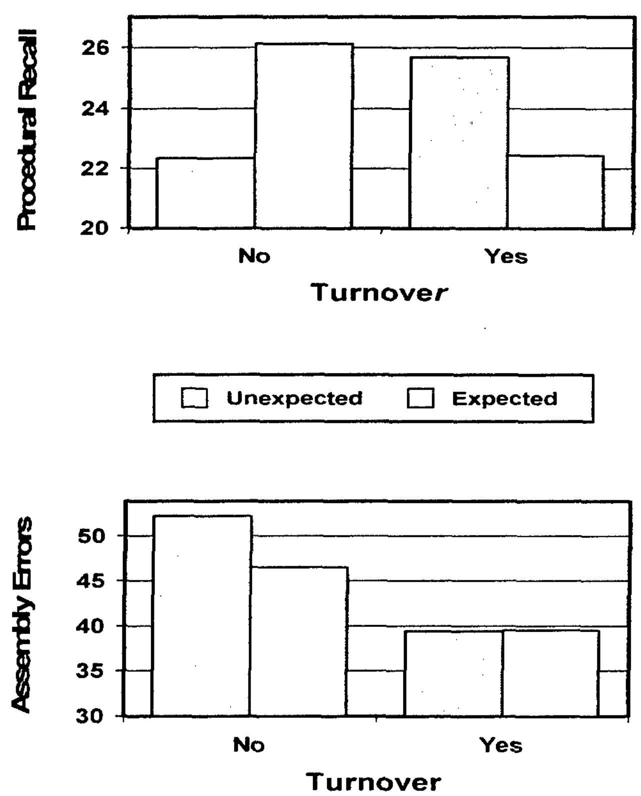

Figure 1. Procedural recall and assembly errors.

Another curious result was a significant ($p < .05$) main effect of whether turnover occurred on assembly errors (see bottom of Figure 1). This effect was the opposite of what one might expect -- *fewer* errors were made by groups that experienced turnover ($M = 39.48$) than by groups whose membership was stable ($M = 49.44$). Why should turnover have this effect? Qualitative data suggested that some newcomers tried hard to learn the task well, so that they could make good impressions on oldtimers in the groups that they were entering. And once newcomers entered those groups, oldtimers also seemed motivated to work hard, so that they could make good impressions on the newcomers. This explanation is tentative and does not account for the interaction effect that we observed in procedural recall.

But if the explanation has merit, then it suggests several new experiments. For example, suppose we manipulated expectations among newcomers and/or oldtimers about how critical the other side would be? When either newcomers or oldtimers expect fellow group members to be more critical, they should try to learn the task more thoroughly during training and perform it better later on. We could also manipulate the external status of newcomers to see whether oldtimers change their behavior accordingly (see Levine, Choi, & Moreland, 2003; Ziller & Behringer, 1960). Oldtimers should try harder to impress newcomers whose status is higher.

Experiment 2. The second experiment that we performed under this contract involved 285 participants, all college students at the University of Pittsburgh. Most of the participants (228) were randomly assigned to 76 groups, each containing three unacquainted persons of the same sex. Other participants served as newcomers for the groups that experienced turnover.

In this experiment, as in the first, the original members of each group were trained together. In one condition, containing 19 groups, there was no turnover. In another condition, containing 17 groups, turnover occurred without warning at the start of the testing session. As before, we created turnover by removing a randomly chosen group member and then replacing him or her with someone who was trained individually. We expected (despite the first experiment) stronger signs of transactive memory, and better group performance, when there was no turnover. We also ran three other conditions. In all these conditions, groups were warned before their training began that turnover would occur at the start of their testing sessions. Again, they were told that one group member (not identified) would be removed and then replaced by someone who was trained individually. That is exactly what occurred, but we also gave either the oldtimers (group members who remained after turnover occurred), the newcomer (the replacement person), or both the oldtimers and the newcomer, written information summarizing the newcomer's skills at building radios, as measured during the training session. There were (respectively) 17, 12, and 11 groups in these conditions. Our approach reflected research by Moreland and Myaskovsky (2000), who found that written information about group members' skills can produce transactive memory systems that are just as helpful as the systems created through group training. Our reasoning was that informing oldtimers about a newcomer's skills might help them incorporate that person into their group's transactive memory system, thereby limiting the harmful effects of turnover on transactive memory and group performance. We expected to see stronger signs of transactive memory, and better group performance, when the oldtimers, or both the newcomer and the oldtimers, received information about newcomer skills, compared to when the oldtimers received no such information or when it was given only to the newcomer.

The results from this experiment were more encouraging. Multiple regression analyses were again carried out, in which group scores on one of the three performance measures, or on the transactive memory index, were regressed on a set of binary variables representing the various conditions, and group gender. Comparable patterns of performance across conditions were found for both procedural recall and assembly errors, though these differences were significant ($p < .05$) only for assembly errors (see Figure 2). As expected, significantly fewer assembly errors were made by groups that experienced no turnover ($M = 32.42$) than by groups where turnover occurred but no information about the skills of new members was provided ($M = 50.65$). And groups made significantly fewer assembly errors when information about those skills was given to oldtimers ($M = 32.47$) than when it was not provided at all. In fact, providing such information to oldtimers helped groups to perform just as well as if turnover never occurred! But it did not seem to matter whether information about the skills of newcomers was given only to oldtimers, or to newcomers ($M = 40.00$), or to everyone ($M = 41.82$). Groups in all these conditions made the same number of assembly errors.

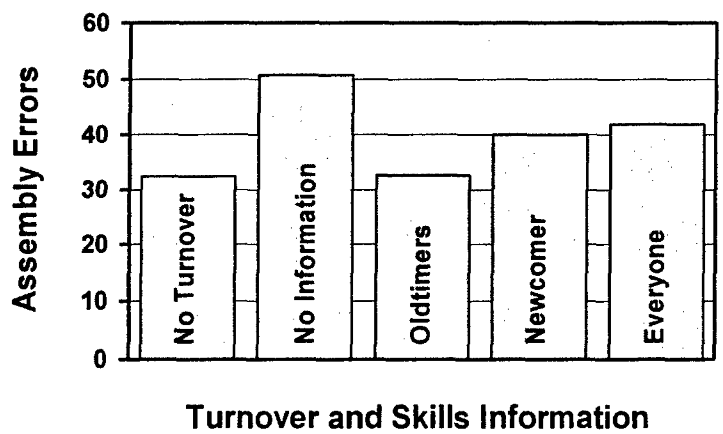

Figure 2. Assembly errors.

Significant ($p < .01$) differences across conditions were also found in the transactive memory index scores (Figure 3), and these were similar to the differences in group performance that we observed. Transactive memory was stronger when groups experienced no turnover ($M = 4.51$) than when turnover occurred, but information about the newcomers' skills was not provided ($M = 3.26$). And transactive memory was stronger when such information was given to oldtimers ($M = 4.40$) than when it was not provided to anyone. In fact, transactive memory appeared to be just as strong when oldtimers received information about newcomers as when no turnover occurred at all. Once again, however, it did not seem to matter whether such information was given only to oldtimers, or to newcomers ($M = 4.09$), or to everyone ($M = 3.94$). Transactive memory was equally strong in all these conditions.

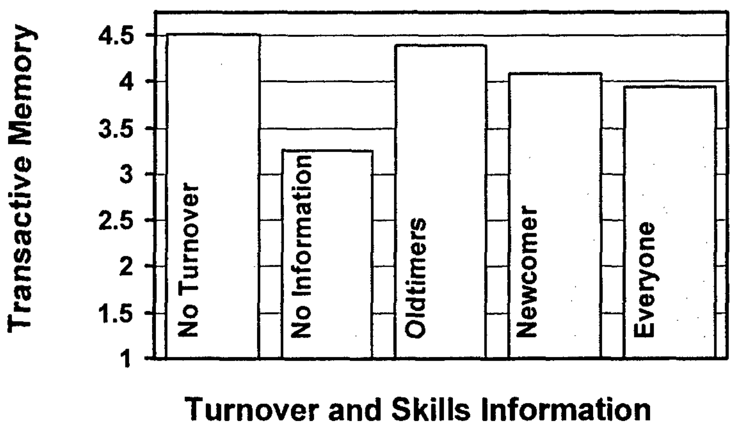

Figure 3. Transactive memory.

As noted earlier, transactive memory has mediated the effects of training on performance in our previous research. To explore that issue in this experiment, we regressed assembly errors on a set of binary variables representing the various conditions, then added transactive memory scores as predictors in a second regression. The first analysis, as might be expected from the results already reported, was significant ($p < .05$). In the second analysis, however, the binary variables lost their predictive power, and transactive memory scores became the only significant predictors of assembly errors. These results suggest that transactive memory indeed mediated the effects of training on group performance, as in our previous work (cf. Baron & Kenny, 1986).

Again, it is not difficult to imagine related experiments that could be performed. Suppose, for example, that we gave newcomers information about how skillful oldtimers are at building radios. This should be helpful too, because it would help newcomers enter the transactive memory systems of their groups more quickly and easily, thereby limiting the harmful effects of turnover on both transactive memory and group performance. There may also be other ways to communicate information about the skills of newcomers and/or oldtimers. For example, written summaries may be less effective than personal introductions, stories about past experiences, or remarks by leaders.

Future Research

Our research suggests the utility of further research on personnel turnover and transactive memory. What should be studied? There are many options. One could vary, for example, the number or types of people who enter or leave groups. In general, more damage to transactive memory and performance should occur in groups that experience more turnover. But are these effects linear? As levels of turnover rise, efforts by group members to preserve transactive memory systems may also increase, but only to a certain point, when people decide that it would be wiser to abandon such efforts and just rely instead on their individual memories. What is that turning point? Do some groups reach it sooner than others, and if so, then why? A related issue is whether transactive memory systems are affected equally by the arrival of newcomers and departure of oldtimers (see Argote, 1999, for an analysis of how each type of membership change can affect group performance). Because oldtimers have been group members longer, they are probably more integral to the operation of such systems. This suggests that their departure would be more disruptive. But for that same reason, it might be easier for groups to adjust their transactive memory systems for the departure of oldtimers, whose knowledge and skills are more familiar. One could also manipulate the overlap between what newcomers and oldtimers know in groups that are experiencing turnover. Turnover should be less damaging to transactive memory systems when newcomers bring to groups valuable knowledge that other members do not already possess. But turnover should be more harmful to transactive memory systems when oldtimers take away from groups valuable knowledge that only they possess.

One could also study how groups learn to cope with turnover. For example, turnover may be less damaging for groups that are older and more experienced. Over time, such groups often change their practices in ways that make turnover less disruptive (see Moreland & Levine, 1988: Ziller, 1965). These changes might involve transactive memory systems, which can sometimes serve as tools for their own preservation. When oldtimers leave groups, for example, it may well be easier for those groups to evaluate what knowledge they are losing when they have already developed strong transactive memory systems. Teams with such systems can arrange for any oldtimers that are leaving to "download" their knowledge in some way before they go (e.g., by recording the information or transferring it to other group members), or encourage the oldtimers to maintain future contact with them (e.g., by developing a consulting relationship), so that they retain access to whatever information they need. Strong transactive memory systems can also be useful for recruiting and socializing new group members. Recruitment is improved because current group members agree about what knowledge their groups need, which helps them to identify who should be encouraged to join their groups. And socialization is improved because current group members know what they want from newcomers, so they can communicate their expectations more clearly and consistently. They can also provide newcomers with more and better information about their own knowledge and skills, which (again) should help newcomers to use those resources.

Finally, an intriguing issue that one might study is how rotation of workers across groups within an organization affects the transactive memory and performance of those groups (see

Moreland & Argote, 2003). As time passes, workers in such an organization may find themselves in groups that contain people with whom they have worked before in other groups. Group members could be somewhat familiar with one another, in other words, even though the group to which they now belong is new and the group(s) to which they once belonged is (are) gone. Prior experience, even in other groups, could help people build transactive memory systems in new groups, especially if the new and old groups were similar. The damaging effects of turnover might be minimized, then, when group members are already familiar with one another. But familiarity could also be problematic in some ways. For example, without knowing exactly what has happened to former colleagues since they last worked together, people may assume that they have not changed and thus treat them in ways that do not reflect gains or losses in their skills. People might also mistrust their former colleagues, precisely because they have been members of other groups (cf. Gruenfeld et al., 2000). To study these complex issues, one could vary such factors as how often people have worked together before in the same groups, how much time has passed between their shared memberships, and how similar the various groups are to one another. Turnover may be less damaging to transactive memory and performance when group members have worked together more often in the past, the time intervals between their shared memberships are shorter, and the new and old groups are more similar to one another.

Potential Applications

Turnover is inevitable in Army groups and can have a variety of harmful effects, including weakened unit cohesion and reduced transactive memory. Several lessons about transactive memory can be learned from our research. First, shared experience among group members is helpful because it fosters the development of transactive memory systems, which enhance group performance. Shared experience can be provided in a variety of ways, such as training group members together (rather than training workers individually and then assembling them into groups) and keeping groups together as long as possible. The latter option, in fact, is now being explored by the Army (see Brown, 2004). But even when efforts are made to keep a group together, turnover occurs. Second, turnover seems to damage transactive memory, especially when turnover is unexpected and dramatic and there is uncertainty about who will be leaving and when he/she will depart. If turnover is expected, and group members know who is leaving and when, then there may be ways to prepare for the membership change (e.g., by downloading any unique knowledge a departing person possesses) and thereby protect the group's transactive memory system, at least to some extent. Finally, it is also helpful for a group to be familiar with new members before they arrive and for newcomers to know something about the people who belong to the group they are entering. In either case, advanced information about the upcoming constellation of skills within the group helps everyone who belongs make better use of those skills, which in turn makes their group more likely to succeed.

Newcomer Innovation

The entry of newcomers into a work group has potentially important implications for members' shared cognition. Our analysis of these implications is informed by a model of group socialization that describes and explains the passage of individuals through groups (Levine & Moreland, 1994; Moreland & Levine, 1982). Two distinguishing features of the model are its emphasis on temporal change and reciprocal influence. The model assumes that the relationship between the group and the individual changes in systematic ways over time and that both parties are potential influence agents. We focus here on the socialization stage of group membership, which begins with the role transition of entry, when a person first joins the group, and ends with the role transition of acceptance, when the new member becomes a full member. During socialization, the group attempts to impart the knowledge, skills, and values that it believes new members must acquire in order to help achieve group goals. Insofar as the group is successful, the new member shows assimilation. Although many new members are passive, simply internalizing whatever they are told, others play a more active role, trying to improve the group's effectiveness. Insofar as the new member is successful, the group shows accommodation.

Besides producing stress in both parties, socialization can either facilitate or inhibit the group's ability to meet its task goals. Although it is often assumed that group performance is enhanced by rapid and complete assimilation on the part of newcomers, this is not always the case (Levine & Moreland, 1991, 1999). In many instances, newcomers possess useful knowledge that would improve group performance if only oldtimers would recognize and utilize it (i.e., show accommodation). Often, however, oldtimers are reluctant to consider, much less accept, newcomers' ideas (Gruenfeld & Fan, 1999), perhaps because they distrust people who have not yet proven themselves, are comfortable with familiar routines (Gersick & Hackman, 1990), or prefer to discuss shared rather than unshared information (Stasser, 1999). In addition, oldtimers usually outnumber newcomers, which means that newcomers are also a numerical minority. This minority status puts newcomers at a disadvantage, as indicated by evidence that minority members have difficulty producing direct influence on majority members (Wood, Lundgren, Ouellette, Busceme, & Blackstone, 1994) and are disliked and rejected by these members (Levine, 1989). However, minority members are not always so weak. They often produce indirect influence (Levine & Thompson, 1996; Wood et al., 1994), and, by using the right kinds of tactics, they may produce direct influence as well (Levine & Kaarbo, 2001). In addition, there is increasing awareness that, at least under certain conditions, newcomers can alter the groups they enter (e.g., Feldman, 1994; Jackson, Stone, & Alvarez, 1993; Sutton & Louis, 1987).

The conditions under which newcomers can change oldtimers' shared cognition were recently analyzed by Levine and his colleagues (Levine et al., 2003; Levine, Moreland, & Choi, 2001; see also Levine & Moreland, 1985). Although newcomers often interfere with group performance, for example by forcing oldtimers to expend time and energy in socialization activities (Levine & Moreland, 1999; Moreland & Levine, 1989), they can also improve this performance by introducing innovations that help the team work more effectively. According to Levine et al. (2003), such innovation is the result of an implicit or explicit negotiation between newcomers and oldtimers, both of whom play an active role during the socialization phase of group membership. In discussing how newcomers' characteristics and behaviors affect their ability to produce innovation, Levine et al. (2003) emphasized newcomers' motivation to introduce change into the team they are entering, their ability to generate ideas that can enhance team performance, and their ability to convince oldtimers to accept these ideas. They argued, for example, that (a) newcomers' motivation to introduce change varies positively with their belief that they can develop good ideas for solving team problems and their perception that their innovation efforts will be rewarded; (b) newcomers' ability to generate useful ideas varies positively with their general and task-specific cognitive skills; and (c) newcomers' ability to convince oldtimers to adopt their ideas varies positively with their status and use of certain behavioral styles (e.g., consistency, assertiveness). In addition, Levine et al. (2003) identified several team characteristics that affect oldtimers' readiness to accept and implement newcomers' suggestions (e.g., openness, composition, staffing level).

Activities

Experiment 1. In our first experiment conducted under the ARI contract (Choi & Levine, 2004), we focused on the conditions under which a newcomer who has just entered a work team can gain acceptance for a suggested change in the team's task strategy. We examined how the team's degree of choice in determining its initial strategy and subsequent performance using this strategy affected its receptivity to the newcomer's innovation attempt.

A potentially important determinant of a newcomer's ability to produce innovation is the team's level of choice in determining its task strategy prior to his or her entry. It seems likely that a newcomer's innovation attempt will be more effective in teams that did *not* have a choice than in teams that did. This prediction is based on the assumption that choice produces commitment and therefore resistance to change. Building on early dissonance research (Festinger, 1957), Kiesler (1971) argued that choice is a central feature of commitment, because choice produces the perception of responsibility for one's decision (see also Cooper & Fazio, 1984). Choice-induced commitment to a decision has several consequences, including selective exposure to information consistent with the decision (Frey, 1986), biased evaluation of its outcome (e.g., Gilovich, Medvec, & Chen, 1995), resistance to counter-persuasion (e.g., Kiesler & Sakamura, 1966), and behavioral persistence in line with the decision (Staw, 1976).

Although the consequences of choice-induced commitment have been studied primarily in individuals, some research has been done using groups. Most of this work has dealt with "entrapment," in which groups escalate their behavioral commitment to failing courses of action in order to justify their sunk costs (e.g., Bazerman, Giuliano, & Appelman, 1984; Dietz-Uhler, 1996; Kameda & Sugimori, 1993). The present study differed from the typical group entrapment study in two major ways. First, because participants in our study did not incur sunk costs prior to the newcomer's entry, we were able to examine the impact of team choice per se, unconfounded with sunk costs. Second, our study investigated how team choice affected behavioral persistence following success as well as failure.

The team's performance prior to the newcomer's entry is also likely to influence his or her ability to produce innovation. This is because failing teams are more likely to be dissatisfied with their performance than are succeeding teams and hence are more motivated to change their task strategy. This argument is consistent with the substantial literature indicating that behaviors followed by negative outcomes are less likely to be repeated than are behaviors followed by positive outcomes (cf. Bandura, 1986). It is also consistent with the argument that failure, or goal blockage, can decrease reliance on routinized behaviors (e.g., Gersick & Hackman, 1990). Evidence that a newcomer's innovation attempt may be more readily accepted in failing than in succeeding groups was obtained by Ziller and Behringer (1960). The present experiment differs from Ziller and Behringer's study in several ways that allow a stronger test of the impact of newcomers as innovation agents (see Choi & Levine, 2004, for details).

Participants in our study were 141 male undergraduates at the University of Pittsburgh, who participated in the experiment to fulfill a course requirement. They were randomly assigned to 47 three-person teams in a 2 (team choice: no choice/choice) X 2 (team performance: failure/success) between-subjects design. Data from three teams were excluded from analysis, because of participants' failure to follow instructions or suspicion about the identity of the newcomer, leaving one hundred and thirty two participants (44 teams, 11 per condition).

Each team worked on an air-surveillance task (TAST) that runs on networked personal computers. [The design of TAST was influenced by the TIDE^2 program (Hollenbeck, Sego, Ilgen, Major, Hedlund, & Phillips, 1997), but differs from it in a number of ways.] TAST was designed to embody many of the challenges that real-world teams face (cf. Driskell & Salas, 1992), including the need to (a) solve problems requiring substantial communication and coordination; (b) process dynamic information that is distributed unequally across team members; (c) rely on computer systems for information acquisition and transmission; (d) operate in stressful environments characterized by time pressure and performance-contingent payoffs; and (e) adapt to role, status, and power differences within the team.

Three participants were brought to the laboratory, seated in cubicles containing personal computers, and told they would work as members of a simulated air-surveillance team. They were also informed that their team's composition would change later in the experiment, because teams often experience member turnover. One member was randomly designated as team leader (Commander), and remaining members were designated as subordinates (Specialists).

During training on the team task, Specialists were taught how to use their computers to monitor eight characteristics of planes flying through a simulated airspace, how to assign parameter values to these characteristics, and how to transmit these values to the Commander. Plane characteristics were: Airspeed (in miles per hour); Altitude (in feet); Angle (the degree of the plane's ascent or descent); Corridor (the plane's position relative to its authorized flight path - inside, on the edge, outside); Direction (the size of the course adjustment needed for the plane to fly directly over the airbase, in degrees); Radar (weather, none, jamming); Range (distance from the airbase, in miles); and Weapons Arming (low ready, medium ready, high ready). After looking up characteristics, Specialists identified their parameter values (1 = low danger, 2 = medium danger, 3 = high danger) using a table (e.g., for airspeed, < 435 mph = 1; 435-570 mph = 2; > 570 mph = 3). The Commander was taught how to integrate this information using a formula that yielded threat values for each plane and how to enter these values into his computer. Because parameter values changed over time, the Specialists had to monitor the planes continually, and the Commander had to update his threat values in a timely manner. In addition to exchanging plane information, team members could exchange messages on other topics using an email system. Following a practice period, participants were informed that they would complete two work shifts on which they could earn 0 to 100 points, depending on the accuracy of the commander's threat assignments. The TAST program stored the computer-based actions of team members (i.e., acquisition of plane information, Commander's threat assignments, communications) and calculated team performance using the accuracy of threat assignments.

The two independent variables were then manipulated. Teams in the choice condition were asked to decide between two strategies, which had been selected to be equally plausible, for assigning Specialists' monitoring responsibilities. The "weight" strategy involved assigning plane characteristics on the basis of how important they were in the Commander's threat formula (e.g., airspeed and corridor had lower weights than direction and weapons arming). According to this strategy, the Specialists would monitor characteristics of equal importance (four characteristics per Specialist). The "range" strategy involved assigning plane characteristics on the basis of how difficult they were to monitor (e.g., radar and weapons arming had narrower ranges of possible values, and hence were easier to monitor, than were airspeed and altitude). According to this strategy, the Specialists would monitor characteristics of equal difficulty (four characteristics per Specialist). Teams in the no choice condition were each assigned a strategy selected by a team in the choice condition, using a yoking procedure. Participants then filled out a questionnaire assessing their commitment to their team's strategy. After completing a 15-minute shift (Shift 1) on the air surveillance task, participants learned that a score of 75 or higher represented good team performance and that their team's actual score was either 65 (failure condition) or 85 (success condition). Participants then filled out a questionnaire assessing their perception of their team's performance.

Participants were then told that they would each receive $3.00 if their team scored 75 or higher in the next shift (Shift 2) and that Specialist B would be replaced by a newcomer who had completed individual training but had not worked as part of a team before. The newcomer (a confederate) then entered the room, and the original Specialist B left. Before beginning work on Shift 2, team members had a get-acquainted emailing period, during which the newcomer suggested a major change in the team's monitoring strategy. This strategy had been selected to represent a plausible, but not demonstrably correct, way of dividing Specialists' monitoring responsibilities. The newcomer wrote, "I thought of something during training that we could try. Instead of dividing up the char how about each spec takes care of all 8 char of each plane. So spec A gets the first plane, I do the second, spec A gets the third, etc. This might be easier and work better. Since I am new I think you guys should decide whether we try my idea. I'll shut up and you can talk to each other. Let me know what you decide." After the newcomer proposed his idea, the Commander and Specialist A used the email system to decide whether to accept this idea or continue using their original strategy.

Shift 2 followed, during which the newcomer looked up and transmitted plane information according to whichever strategy the Commander and Specialist A had selected. Following this shift, team members received feedback indicating that they had earned the bonus. After completing a final questionnaire, participants were debriefed, paid $3.00, and dismissed. The experiment took approximately two hours.

As expected on the basis of pilot work, approximately half of the teams chose each of the two monitoring strategies (weight strategy = 59%, range strategy = 41%). Audiotapes revealed that team discussions focused on identification of members' personal strategy choices, reasons for these choices, and various TAST functions (e.g., how to abbreviate names of plane characteristics). Teams generally reached a decision within five minutes. Neither the strategy the team chose nor the length of its discussion predicted later acceptance/rejection of the newcomer's suggestion.

The success of the team choice manipulation was assessed using two 9-point scales contained in the questionnaire completed prior to Shift 1: "How effective do you think this strategy will be?" (9 = V*ery Effective*) and "How personally committed do you feel to this strategy?" (9 = V*ery Committed*). Because participants' responses to these items were highly correlated, they were averaged to yield individual composite scores and then aggregated to yield a team-level score. A *t*-test revealed, as expected, that team-level scores were significantly higher ($p < .01$) in the choice than in the no choice condition (*M*s = 7.89 and 6.85, respectively).

An analysis was also conducted on team members' expectations about working on their team prior to Shift 1 ("Overall, how much do you think you will like working on this team?" (9 = V*ery Much*). Responses to this question were also aggregated at the team level and analyzed using a *t*-test, which revealed significantly more positive expectations ($p < .01$) in the choice than in no choice condition (*M*s = 8.11 and 7.21, respectively). It is worth noting that the mean performance of teams in the choice ($M = 45.43$) and no choice ($M = 46.19$) conditions did not differ significantly during Shift 1.

The success of the team performance manipulation was assessed using two items in the questionnaire completed after Shift 1 and before the newcomer entered the team: "How well did your team perform in this shift?" (9 = V*ery Well*), and "How useful was the strategy that the experimenter provided (no choice condition) or your team decided on (choice condition) for dividing the plane characteristics?" (9 = *Very Useful*). Participants' responses to these items were averaged to yield individual composite scores and then aggregated. A team choice X team performance analysis of variance indicated, as expected, that performance was perceived as significantly higher ($p < .01$) in the success than failure condition (*M*s = 7.48 and 5.52, respectively). In addition, participants viewed their performance as significantly higher ($p < .01$) in the choice than in the no choice condition (*M*s = 6.91 and 6.09, respectively).

The questionnaire completed after Shift 1 also asked participants: "How much did you like working on this team?" (9 = *Very Much*). A team choice X team performance analysis of variance conducted on aggregated responses to this question yielded significant main effects (*p*s < .01) for both team choice ($M = 6.74$ for no choice; $M = 7.76$ for choice) and team performance ($M = 6.53$ for failure; $M = 7.97$ for success). Moreover, a significant team choice X team performance interaction ($p < .01$) was obtained, indicating that participants in the no choice condition liked working on their team significantly more ($p < .01$) when they succeeded than when they failed (*M*s = 7.76 and 5.72, respectively), whereas participants in the choice condition did not differ significantly (*M*s = 8.17 and 7.35 in the success and failure conditions, respectively).

The dependent variable, team acceptance or rejection of the newcomer's proposed innovation, was measured by examining the messages exchanged between oldtimers (i.e., the Commander and Specialist A) after the newcomer proposed his strategy. Two coders blind to experimental conditions classified teams in terms of whether the Commander and Specialist A accepted the newcomer's strategy or adhered to their original strategy. In all cases, the two coders made identical decisions regarding team acceptance/rejection of the newcomer's suggestion.

Figure 4 shows the proportion of teams that accepted the newcomer's suggestion in the four experimental conditions. A hierarchical log-linear analysis was conducted to assess the impact of team choice, team performance, and their interaction. Consistent with predictions, the main effects for both team choice ($p < .01$) and team performance ($p < .01$) attained significance. The newcomer's suggestion was accepted approximately twice as often (a) in the no choice than choice condition (73% versus 36%) and (b) in the failure than success condition (77% versus 32%). It is worth noting that over 90% of no choice/failure teams accepted the newcomer's suggestion, whereas fewer than 10% of choice/success teams did so.

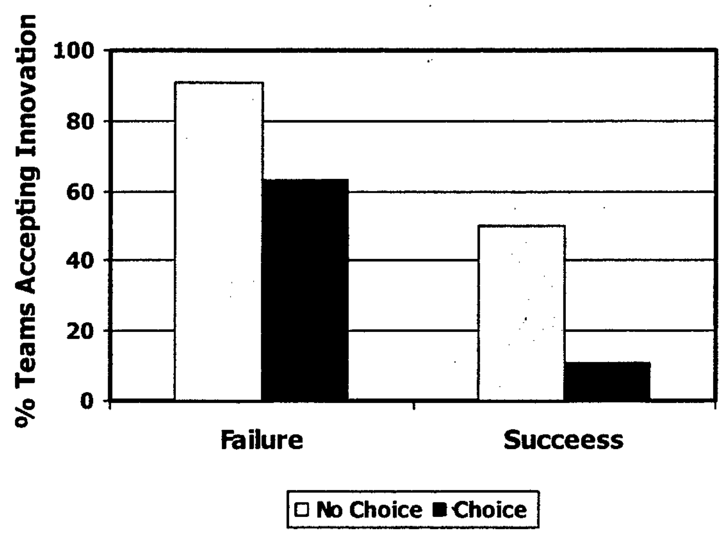

Figure 4. Team receptivity to newcomer innovation.

To assess how much oldtimers included the newcomer in their discussion, we calculated for each team the proportion of messages that oldtimers directed to the newcomer after he made his innovation proposal (newcomer messages/total messages), using data in the computer log files. After an acrsine transformation, these proportion scores were analyzed using a team choice X team performance analysis of covariance, in which the proportion of messages directed to the newcomer before his innovation proposal (arcsine transformed) served as a covariate. Results showed that the newcomer received significantly fewer messages ($p < .05$) in the choice than in the no choice condition (*M*s = .34 and .42, respectively).

In summary, the purpose of this study was to investigate newcomer innovation in work teams. As predicted, newcomer innovation was more successful when teams were assigned rather than chose their strategy and when this strategy produced failure rather than success. What factors were responsible for these effects? As noted earlier, manipulation check questions indicated, as expected, that (a) commitment to the team strategy before Shift 1 was higher in the choice than no choice condition and (b) perceived performance after Shift 1 was higher in the success than failure condition. Results also indicated that perceived performance after Shift 1 was higher in the choice than no choice condition.

To better understand the mechanism(s) underlying the impact of team choice on receptivity to newcomer innovation, we conducted mediational analyses involving commitment and perceived performance (Baron & Kenny, 1986). As Figure 5 indicates, the necessary conditions for mediation were satisfied for both analyses. In each case, the independent variable was related to the mediator; the independent variable was related to the dependent variable; the mediator was related to the dependent variable; and the relationship between the independent and dependent variables was smaller when the mediator was present than absent. More specifically, the relationship between team choice and receptivity to innovation ($p < .05$) became nonsignificant when commitment was added to the equation, and a Sobel test indicated that the indirect effect of the independent variable on the dependent variable via the mediator was significantly different from zero ($p < .05$). Moreover, the relationship between team choice and receptivity to innovation also became nonsignificant when perceived performance was added to the equation, and a Sobel test was significantly different from zero ($p < .05$). Taken together, these mediational analyses suggest that team choice influenced receptivity to newcomer innovation via two routes – through commitment to the team's strategy before Shift 1 and through perception of the team's performance after Shift 1.

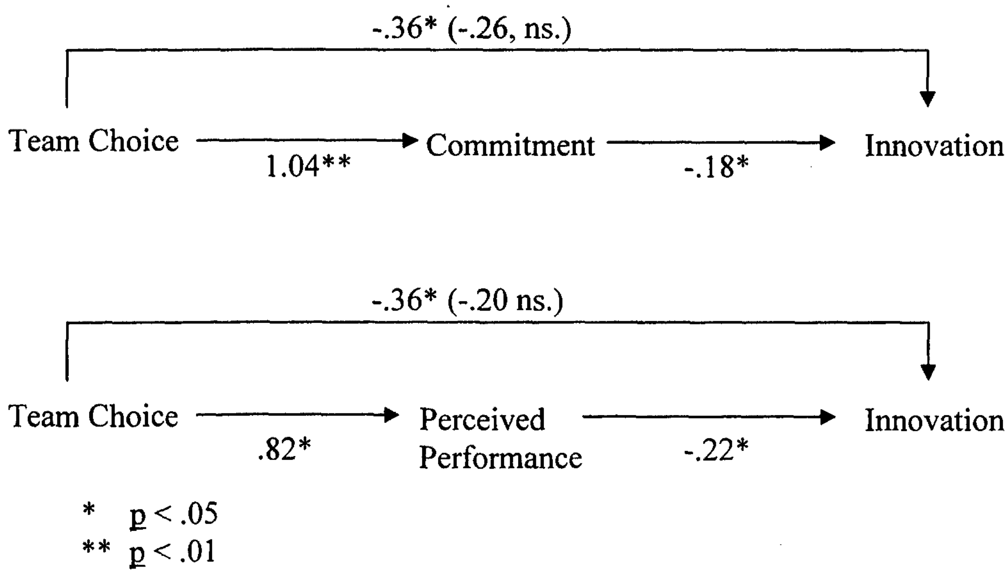

Figure 5. The mediational role of commitment and perceived performance.

The impact of team choice was further revealed in other analyses. Prior to Shift 1, participants in the choice condition had more positive expectations about working on their team than did those in the no choice condition. After Shift 1, participants in the no choice condition liked working on their team more when they succeeded than when they failed, whereas those in the choice condition had equally (and strongly) positive reactions regardless of their team's performance. Finally, participants in the choice condition directed fewer communications to the newcomer than did those in the no choice condition. These findings suggest that team choice was an important determinant of participants' reactions in the present study.

Although our results provided strong support for our hypotheses, there may be conditions under which team choice and team performance yield different effects. In regard to choice, how long a team has used a particular task strategy may be important, because strategies employed for long periods often become routinized and resistant to change (Gersick & Hackman, 1990). In such cases, newcomers' innovation attempts may be rejected even if team members had no choice in their strategy (i.e., used an assigned strategy). The perceived utility of an assigned strategy also may be important. In the present study, participants in no choice condition were informed that they had been randomly assigned one of many possible strategies. This information may have reduced the perceived utility of the strategy and thereby increased participants' receptivity to the newcomer's innovation attempt. In contrast, if participants are assigned an allegedly effective strategy (e.g., one used by successful teams), they may not accept the innovation attempt. Finally, the impact of team choice may be affected by the conditions under which the strategy decision is made. In the choice condition of the present study, participants were told to reach consensus. Given that a unanimity decision rule increases group members' commitment to their decision (cf. Kameda & Sugimori, 1993) and satisfaction with it (cf. Miller, 1989), participants in our choice condition may have experienced especially strong commitment to their strategy. In contrast, if choice teams use a more lenient decision rule, such as the majority rule, they may experience less commitment to their strategy.

In regard to team performance, the amount of behavioral change needed to implement the innovation may be important. In the present study, the actions required by the newcomer's suggested strategy were not strikingly different from those required by the team's current strategy. In contrast, if the suggested strategy requires dramatic behavioral change, even failing teams may be unwilling to adopt it. The impact of team performance also may be influenced by how this performance compares to relevant standards. In the present study, participants in the failure condition fell short of the success criterion by only 10 points on a 100-point scale, which may have led them to believe that, by accepting the newcomer's suggestion, they would succeed in Shift 2. In contrast, if team performance falls far short of the success criterion (e.g., 40 points below the criterion), team members may experience "learned helplessness," leading them to believe that they are doomed to failure in Shift 2 no matter what they do.

Experiment 2. Although newcomers are often portrayed as passive recipients of influence, our study revealed that they can play an active role in the teams they enter by introducing new ideas designed to improve team effectiveness. In our second ARI-sponsored experiment, we investigated the impact of an additional variable, namely the newcomer's communication style, on the team's responsiveness to a suggested innovation. Jentsch and Smith-Jenstch (2001) have suggested that members of teams use three communication styles, which are differentially effective in producing influence. One style, passivity, is manifested by questions or vague statements. Because it signals reluctance to take personal responsibility for one's beliefs, passivity often fails to attract the attention of other team members and hence produces little influence. A second style, aggressiveness, is manifested by direct statements that reflect disregard for other team members' perspectives. Because it signals hostility, aggressiveness often elicits negative emotional reactions and hence produces little influence. Finally, a third style, assertiveness, is manifested by direct statements that do not contain hostility. Jentsch and Smith-Jentsch (2001) suggested that assertiveness produces more influence than does either passivity or aggressiveness (see also Salas, Fowlkes, Stout, Milanovich, & Prince, 1999).

The assumption that communication style is an important determinant of social influence is consistent with work on "behavioral style" in the minority influence literature. It has been argued that behavioral style is the major factor underlying the ability of numerical minorities to influence numerical majorities (as well as vice versa) (Moscovici, 1976, 1985). Minority influence is relevant to newcomer innovation, because newcomers are often numerical minorities in the teams they join.

Moscovici (1985) discussed three behavioral styles relevant to our present purposes: autonomy, consistency, and rigidity. An autonomous behavioral style is manifested by independence and objectivity. Independence implies strong convictions and character, whereas objectivity implies unbiased information processing. According to Moscovici, a highly autonomous minority produces more influence than does a less autonomous one. A consistent behavioral style is manifested by opinion stability over time, as well as by agreement among minority members. According to Moscovici, a consistent minority produces more influence than does an inconsistent one. Finally, a rigid behavioral style is manifested by extreme, inflexible behavior that indicates refusal to make concessions. According to Moscovici, rigidity produces less influence than does flexibility, particularly when direct opinion change (involving the specific topic under discussion) is involved (cf. Mugny, 1982). Because assertiveness, as defined above, reflects high autonomy and high consistency (as well as low rigidity), this communication style is likely to increase a newcomer's persuasive power.

In addition to manipulating the newcomer's communication style (assertive vs. nonassertive), we also manipulated the team's performance prior to the newcomer's entry (success vs. failure). We predicted a main effect of newcomer assertiveness, such that teams would be more responsive to the newcomer's strategy suggestion when he was assertive than when he was non-assertive. In addition, based on Choi and Levine (2004), we predicted a main effect of team performance, such that teams would be more responsive to the newcomer's strategy suggestion when they had previously failed than when they had previously succeeded. Finally, we predicted a communication style x team performance interaction, such that failing teams would be more responsive to the newcomer's communication style than would succeeding teams. Specifically, failing teams were expected to accept the newcomer's suggestion substantially more often when he was assertive than when he was non-assertive, whereas succeeding teams were expected to show a weaker tendency in this direction. This hypothesis was based on the assumption that failing teams, which are highly motivated to improve their performance and hence relatively open to changing their current task strategy, would be more sensitive to the quality of advice they receive from a newcomer than would succeeding teams, which are not highly motivated to improve their performance and hence relatively closed to changing their strategy. Given that the only available cue about the quality of the newcomer's advice is his communication style (assertive > nonassertive), failing teams should be more influenced by this variable than should succeeding teams.

The methodology in this experiment was very similar to that used in our first experiment, with three major exceptions. First, rather than varying whether teams chose or were assigned their initial task strategy, all teams were allowed to choose their strategy.

Second, the assertiveness of the newcomer's strategy suggestion was manipulated. The nonassertive newcomer said: "I had an idea in training. What do you guys think about each spec doing all 8 characteristics for a plane? So, spec A would get the first plane, I do the second, spec A gets the third, etc. I'm not sure this would work, but I'm tossing it out anyway. You guys discuss it and let me know what you think." The assertive newcomer said: "I had an idea in training. I think each spec should do all 8 characteristics of a plane. So, spec A would get the first plane, I do the second, spec A gets the third, etc. I'd bet anything that would work great. You guys discuss it and let me know what you think."

Finally, for exploratory purposes, we added another variable -- the alleged difficulty of the task in Shift 2. In the increased difficulty condition, participants were told, following Shift 1, that task difficulty would increase in Shift 2. In the stable difficulty condition, participants were told that task difficulty would remain the same. We were interested in whether the expectation of increased task difficulty would increase participants' responsivity to newcomer assertiveness in the success condition.

Participants were 489 male undergraduates at the University of Pittsburgh, who participated in the experiment to fulfill a course requirement. They were randomly assigned to 163 three-person teams in a 2 (communication style: assertive/non-assertive) X 2 (team performance: success/failure) X 2 (expected task difficulty: increased/stable) between-subjects design. Data from 19 teams were excluded from analysis for various reasons, leaving 432 participants (144 teams). The number of teams in each condition was as follows: assertive/success/increased: 19; assertive/success/stable: 18; assertive/failure/increased: 19; assertive/failure/stable: 17; nonassertive/success/increased: 18; nonassertive/success/stable:17; nonassertive/failure/increased: 17; nonassertive/failure/stable: 19.

Following Shift 1, participants were asked to report their team's score on that shift; 99% responded accurately. In addition, participants were asked how useful their strategy had been on Shift 1 (9 = *Very Useful*). A t test on participants' responses (aggregated at the team level) indicated that success teams perceived their strategy as significantly more useful ($p < .01$) than did failure teams (*M*s = 7.03 and 5.95, respectively). Participants were also asked how they expected their team to perform in Shift 2 (1 = *Much Worse than Shift* 1; 9 = *Much Better than Shift 1*). A t test revealed that success teams had significantly lower expectations ($p < .05$) than did failure teams (*M*s = 6.51 and 6.91, respectively). This finding is not surprising, given that (a) participants were asked to assess how their Shift 2 performance would compare to their Shift 1 performance and (b) success teams were already performing at a very high level.

The dependent variable, team acceptance or rejection of the newcomer's proposed innovation, was again measured by examining the messages exchanged between oldtimers (i.e., the Commander and Specialist A) after the newcomer proposed his strategy. Intercoder reliability was again high. A hierarchical log-linear analysis was conducted to assess the impact of communication style, team performance, expected task difficulty, and their interactions.

Consistent with our prediction, the main effect for team performance was significant ($p < .01$), with 75% acceptance in the failure condition and 46% acceptance in the success condition. Whereas the predicted main effect for communication style was not significant, the predicted interaction between communication style and team performance was marginally significant ($p < .10$). Specifically, failing teams were more likely to accept the newcomer's suggestion if he was assertive rather than nonassertive, whereas this was not the case in the succeeding teams. Figure 6 shows the proportion of teams that accepted the newcomer's suggestion in the four communication style X team performance conditions. Finally, it should be noted that expected task difficulty did not significantly influence acceptance of the newcomer's suggestion.

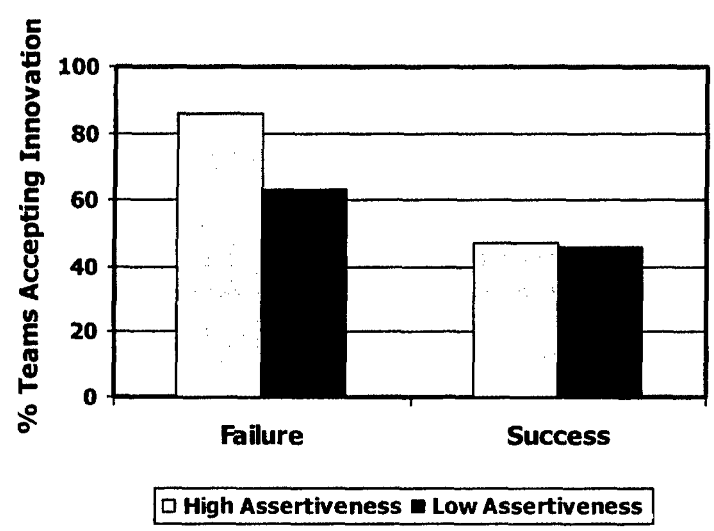

Figure 6. Team receptivity to newcomer innovation.

Following Shift 2, participants were asked three questions about (a) the newcomer and (b) the other oldtimer (either Specialist A or the Commander, depending on the participant's own position). These questions dealt with how confident the target person was in the correctness of his views (9 = *Very Confident*); how well he did his job (9 = *Very Well*); and how much the participant liked working with him (9 = *Very Much*). Participants' responses were aggregated at the team level, and correlations were used to measure the relationship between (a) team rejection/acceptance (rejection = 0; acceptance = 1) of the newcomer's suggestion and (b) the target person's perceived confidence, job performance, and likeability. Results indicated significant positive relationships for the newcomer on all three questions ($p < .01$). In contrast, only the confidence measure yielded a significant (positive) relationship for the other oldtimer ($p < .05$). The consistency and strength of the correlations for the newcomer suggest that teams' response to the newcomer's innovation attempt (acceptance vs. rejection) may have influenced their subsequent evaluations of him.

Although the predicted communication style X team success interaction was only marginally significant in the present study, it suggests that our hypothesis has merit and deserves further investigation. Given that our manipulation of communication style was relatively subtle, a future study might employ a stronger version this variable, in which the assertive newcomer advocates his position more vigorously. We are currently pilot testing such a revised manipulation and plan to test its impact in a subsequent experiment.

Future Research

A number of additional hypotheses about team receptivity to newcomer innovation are worth investigating in future studies. Because these hypotheses are discussed in detail by Levine et al. (2003), they are simply listed here. According to Levine et al. (2003), successful newcomer innovation is more likely to occur when:

(a) Newcomers have high status in the team
(b) Two or more newcomers advocate the same position
(c) Newcomers earn "idiosyncracy credits" by conforming to team norms before attempting to change in these norms
(d) Newcomers are expected to remain in the team for a relatively long period
(e) The team has a tradition of openness to new members
(f) Newcomers are similar to current team members on demographic and experiential dimensions
(g) The team is understaffed (i.e., does not have enough members to accomplish its tasks)
(h) The team is in an early stage of development
(i) The team is low in cohesion
(j) The team has a climate favoring innovation
(k) The team has democratic leadership

Potential Applications

Newcomers are a particularly valuable source of information in organizations composed of hierarchically-organized teams with well-learned task strategies. Because the norms of such teams place strong pressures on members to follow standard operating procedures, these teams sometimes display high levels of rigidity, which in turn produce disastrous errors that compromise the missions of both the team and the larger organization in which it is embedded. Many examples in military and other settings can be cited (e.g., the USS Vincennes attack on a civilian airliner, commercial plane crashes). A major reason why teams fail to respond appropriately to new and unexpected situations is because valuable knowledge possessed by people in subordinate positions is not brought to bear on the team's task (Milanovich, Driskell, Stout, & Salas, 1998). This can occur for two reasons. In some cases, subordinates do not provide useful information because they believe their superiors will respond with indifference or hostility. In other cases, subordinates overcome these concerns and provide valuable information, only to have it ignored by superiors.

Our work is predicated on the assumption that people in subordinate positions who are also newcomers can sometimes facilitate a team's performance. We believe that newcomers are a potentially valuable source of task-relevant knowledge precisely because they are new -- that is, because they have not been socialized to accept the team's task procedures and hence can suggest alternative procedures that may facilitate team performance. Our research has begun to identify some of the variables that enhance a newcomer's ability to produce influence, including whether the team chose or was assigned its initial task strategy, whether the team had failed or succeeded prior to the newcomer's entry, and whether the newcomer proposed his or her innovative idea in an assertive or a nonassertive manner. Further research on the factors that facilitate/inhibit newcomers' motivation and ability to produce innovation may suggest strategies for helping Army teams make better use of new members.

Simulation Research

Computational analysis is playing an increasingly important role in the development of theories of complex systems, such as groups, teams, and organizations. This work stems from a growing recognition that the underlying processes of such systems are complex, dynamic, adaptive, and non-linear; that system behavior emerges from interactions within and between the agents and entities that comprise the unit (people, sub-groups, technologies, etc.); and that the relationships among these entities both constrain and enable individual and unit level action (Carley & Lee, 1998). Another reason for interest in computational approaches is the recognition that units are inherently computational, since they have a need to scan and observe their environment, store facts and programs, communicate among members and with their environment, and transform information by human or automated decision making. The aim of computational research -- to build new concepts, theories, and knowledge about complex systems -- is being met through the use of a wide range of computational models, including computer-based simulation, numerical enumeration, and emulation models that focus on underlying processes. These computational models are used to describe complex systems and to generate hypotheses about their behavior under different scenarios. These hypotheses, in turn, serve as guides for designing human studies and suggest what data to collect in laboratory and field settings. Particularly useful are process models of non-linear systems in which multiple factors dynamically interact.

One of the most effective ways of using computational models is by running virtual experiments. In a virtual experiment, data for each cell in the experimental design are generated by running a computer simulation model. In generating this experiment, standard principles of good experimental design are followed, and the data are then analyzed statistically. There are many synergies for research programs that employ both computational models and human experiments. First, computational models are valuable for generating hypotheses that can be tested using human groups. Second, computational models make it possible to run a series of virtual experiments that extend laboratory conditions (e.g., by investigating how personnel turnover affects teams varying widely in size). Such experiments enable sensitivity analyses to be conducted on laboratory results and thereby increase the generalizability of these findings. Third, data obtained in experimental studies can be used to validate, refine, and elaborate simulation models.

Both of the computational models we use, OrgAhead and Construct, have been used to conduct virtual experiments and have proven useful in predicting the behavior of teams and organizations undergoing turnover. Our previous research combining virtual and human laboratory experiments has improved our understanding of team learning, particularly with respect to the effects of knowledge distribution and the impact of roles and interaction. It also has demonstrated the value of different levels of model validation and increased our understanding of how to design computational models and measures of teams so that there is a direct mapping between the simulated teams in the computational model and the human teams in the lab and field.

The research we conducted examined turnover using computer simulation. Our basic approach is termed dynamic network analysis. This approach combines multi-agent modeling and network analysis to produce and use empirically grounded computational models (referred to as multi-agent network models). In the CASOS lab, the focus has been on the simulation studies, linking the simulations to the experimental studies, tuning and validating the simulation models, and then using the tuned simulation models to generate a series of hypotheses regarding turnover and team behavior. These hypotheses and the associated results consider other variables not explored in the human laboratory experiments, including logics for interaction and different scales of analysis, such as larger groups, longer time periods, higher levels of change, and more devastating levels of turnover. In all cases we examine how to make teams resilient in the face of turnover and consider: (1) cognitive, social, and information technology factors; (2) impact of one or more personnel leaving; (3) impact of new members; and (4) how to destabilize the teams.

The dynamic network analysis approach combines traditional social networks with multi-agent modeling, which results in multi-agent network modeling. It utilizes multiple matrices (meta-matrix) resulting in multi-mode, multi-plex networks to represent the team structure (see Table 1). Connections among nodes in these matrices or networks are flexible and vary in strength. This representation is used to capture data from both the lab and virtual experiments that were run. The models take such meta-matrix data as input and, using complex adaptive system techniques, evolve them. In doing this network adaptation, the models account for characteristics of agents, resources, events, characteristics of connections or linkages, and processes for change – such as learning, resource consumption, and tension. Since the resulting networks evolve and can be measured and contrasted at varying levels, the associated data is really a hypercube (see Figure 7).

	People / Agents	Knowledge / Resources	Tasks	Group/ Organizations
People / Agents	Social Network	Knowledge Network	Assignment Network	Membership Network
Knowledge / Resources		Information Network / Substitutes	Needs Network	Core Capabilities
Tasks			Precedence Ordering	Institutional Relation
Group/ Organizations				Inter-organizational Network

Table 1. Meta-matrix for real and virtual data.

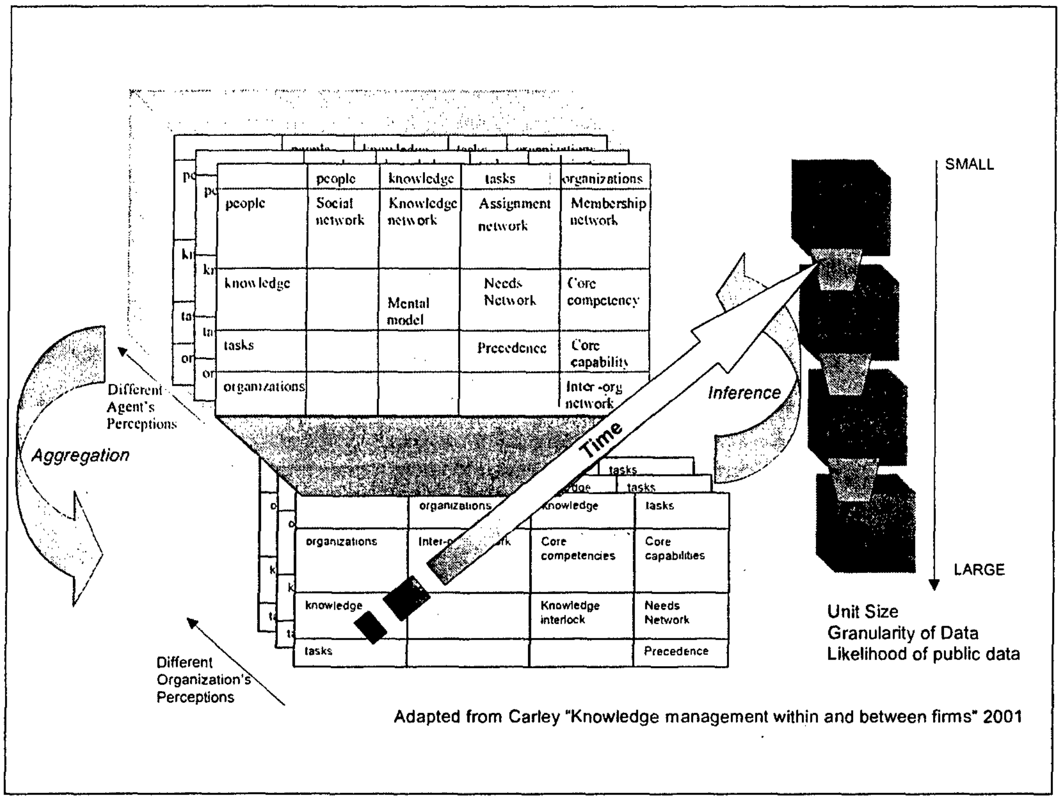

Figure 7. HyperCube representation of data.

The simulation tools that we developed/extended are Construct and OrgAhead. Construct is used to emulate the production task, and OrgAhead is used to emulate the decision making task. Construct and OrgAhead are powerful computer programs that have proven useful in modeling group and organizational performance. We examined two team tasks - decision making (OrgAhead) and production (Construct). These tasks were chosen due to the high frequency with which teams typically do them and the fact that they were being studied in the lab experiments. By using the same tasks in the human and simulated virtual experiments, it was possible to replicate and extend the human lab results to a broader context using the simulations. This strategy also enabled the tuning and validation of the computational tools, which are both multi-agent networks models. In this research these models were used to extend the laboratory work by investigating the impact of turnover in larger social units, under different technology configurations, and over longer time periods. Both simulation models are flexible and can take data at varying levels of granularity.

As part of this work, we have developed metrics given the meta-matrix (see Table 1) for assessing who is critical in the short and long run for assessing impact on an adaptive system which can be used with simulated or real data. These metrics enable the evaluation of why turnover in some cases benefits and at other times harms performance. The answer lies in whether or not, and how, the person/agent was critical to the team. For the lab experiments for which we had data, we developed the meta-matrix data by hand. We then calculated a series of vulnerabilities. Next, we correlated performance with the type of vulnerability represented by the newcomer or the person leaving. This helped identify how the role the person/agent played in the team affected performance.

Toward the end of this program, we were able to leverage the work on another project in which the measures of criticality we developed for this study of turnover were integrated into a general tool for risk analysis called ORA. ORA can take any meta-matrix data and identify vulnerabilities. Since both Construct and OrgAhead can read/write meta-matrix data, ORA can be used to examine and compare the input (real human team structures) and the output (simulated team structures after changes such as turnover). The interaction of these tools is shown in Figure 8. Specific additions to the simulation tools to make this possible are described later.

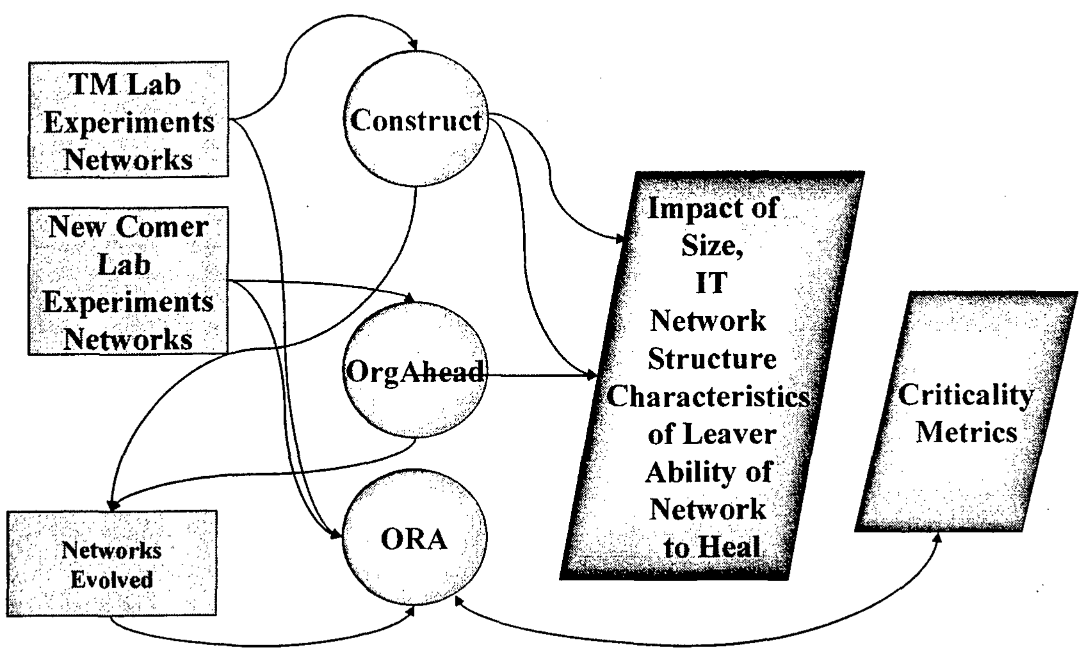

Figure 8. Inter-relation of CASOS tools as used to study turnover in teams.

Construct

Construct is a multi-agent network model for the co-evolution of agents and socio-cultural environments (Carley, 1990, 1991). Construct is designed to capture dynamic behaviors in organizations with different cultural and technological configurations. Construct models groups and organizations as complex systems and captures the variability in human, technological, and organizational factors through heterogeneity in information processing capabilities, knowledge, and resources. The non-linearity of the model generates complex temporal behavior due to dynamic relationships among agents. Agents are decision-making units and can represent various levels of analysis such as individuals, groups, or organizations. The Construct model is grounded in structuration theory (Giddens, 1984), social information processing theory (Salancik & Pfeffer, 1978) and symbolic interactionism (Manis & Meltzer, 1972). The basic interaction mechanism embodies three empirical generalizations: knowledge acquisition occurs through (1) interaction (Festinger, 1950; Granovetter, 1974), (2) homophily (Lazarsfeld & Merton, 1954; McPherson & Smith-Lovin, 1987), and (3) social relativity (Festinger, 1954; Merton, 1968).

Activities. In order to use Construct to extend the lab experiments on the production task, we expanded Construct to have an additional task (effort) so that the agents could operate on the basis of task knowledge and/or transactive knowledge. We also added a GUI interface and enabled all results to be stored in CSV files for ease of import to statistical analysis tools. We also enabled Construct to generate output in a format readable by ORA so that changes in personal vulnerability could be added.

Using the expanded Construct, we conducted a series of simulation experiments to replicate and extend those done by Argote and Moreland on transactive memory, turnover, and team performance. This generated a number of results. First, using Construct, we were able to duplicate the human lab experimental transactive memory setup for groups of three and to replicate the results. We found, using Construct, that group training builds transactive memory, enables more complex transactive memory, and enables faster performance. These results are significant in the real and virtual experiments. In addition, we found that group training enables more accurate transactive memory and fewer errors. These results were significant in the human lab experiments and in the same direction, but not significant, in the simulated (virtual) experiments. Secondary analysis suggests that the difference between the humans and the artificial agents is that the simulated agents are not guessing as much as humans and we may have done too few simulated runs.

One implication of this work is that teams do benefit from transactive memory. Training that enhances transactive memory becomes a force multiplier. Further simulations showed that newcomers, due to lack of transactive memory, disrupt group performance. Another implication of this work is that the Construct model has been validated and can be used for larger groups (although it may be under-predicting the value of training). Utilization of Construct to model larger groups demonstrated a curvilinear value to transactive memory, such that for very small or very large groups the benefits added are negligible. In particular, transactive memory is more valuable in moderately sized groups (15-21 members) than in larger or smaller groups (see Figure 9, in which fewer time periods indicate faster decision making).

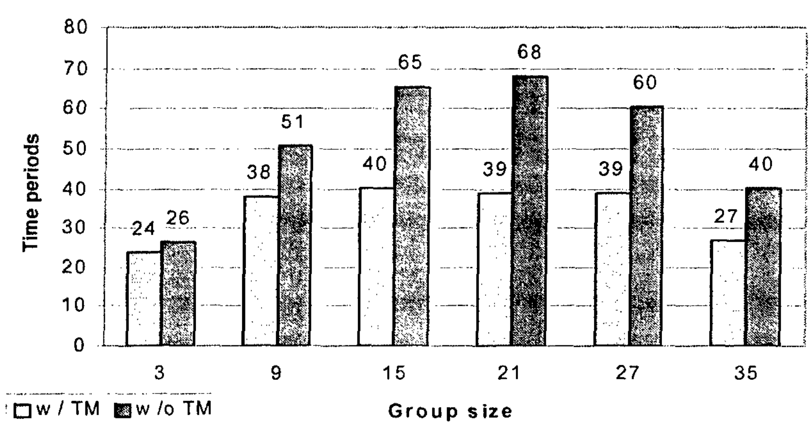

Figure 9. Value of transactive memory for groups of diverse sizes.

A second virtual experiment was done to look at the impact of changes in the task environment (the team's mission). Here we found that, the more often the mission changed (oscillate > switch > never), the greater the value of transactive memory to the group (Figure 10). We also found via simulation that databases containing task information cannot substitute for transactive memory, although databases containing information on who to approach for what may be a partial substitute. In groups with more than abut 50 people, information technology is likely needed to supplement transactive memory.

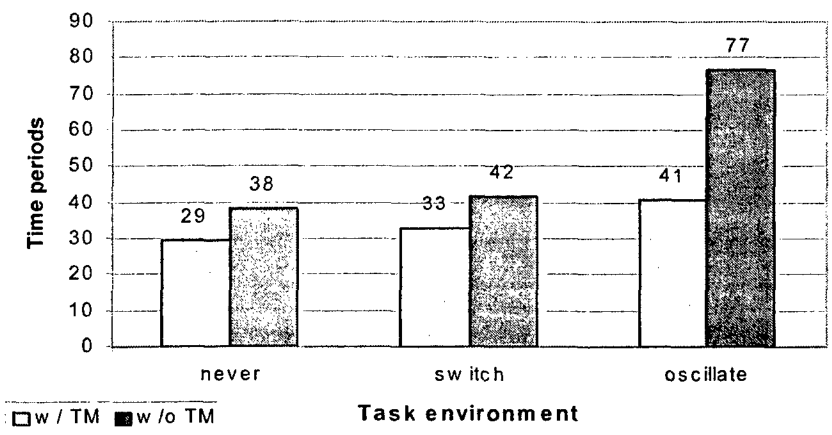

Figure 10. Value of transactive memory relative to the number of changes in the task environment.

Potential applications. There are numerous implications of this work for the Army. First, it suggests that training together is critical for commands of 15-21 people (therefore for platoons), but less so for much larger (such as a brigade) or smaller (such as section or squad) units. It is important to note that in small units (such as sections and squads), transactive memory is picked up very rapidly with or without extensive group training. Second, this research suggests that it may be possible to reduce the impact of rotation on a unit's performance through the use of databases that capture information on who knows what (cf. Moreland & Myaskovsky, 2000). Having such information should increase situation awareness. In future work, we propose to explore whether such tools would be of benefit to the warfighter.

Our simulation work has a number of other potential applications. For example, the new version of Construct can be used to examine simultaneous strategies for stabilizing one's own group/organization and destabilizing an opposing group/organization. For example, it can be used to look at the impact of (a) recruiting new members to one's group or increasing the commitment of current members and (b) isolating members of an opposing group (e.g., enticing them to defect, reducing their operational capability, or physically eliminating them (e.g., Levine, Moreland, & Ryan, 1998)). As such, this simulation is potentially useful for counter-terrorism studies.

We have, in a series of related studies, applied Construct to evaluate the effectiveness of different leadership styles at NASA and the effect of isolating key actors for Covert Networks. This latter work was so successful that we will be building an extension to Construct called DyNet for examining the dynamics of covert networks.

OrgAhead

OrgAhead is a computational model of organizational learning and decision-making (Carley & Lee, 1996). The simulated organization consists of agents whose communication structure resembles hierarchies and whose primary goals are to learn the correct decision or answer to one or more tasks, which are in the form of objective functions, typically the majority classification task. We refer to these task functions as the task environment. The organization also seeks to adapt to an optimal structure under the specified, and possibly changing, task environment by admitting changes in the form of turnover and reassignment of personnel and tasks. OrgAhead can be used to test various aspects of real life organizations, such as complexity in the task environment and constraints on structure and adaptability, under the intellective paradigm of simulating models. An intellective model contains analogous entities, constructs, and complexities of the modeled organizations rather than mimicking each specific behavior.

The look-ahead ability can be used in conjunction with one of two optimization heuristics, hill-climbing or simulated annealing (Carley & Svoboda, 1996). With hill-climbing, the organization selects only beneficial moves or changes at every opportunity for change. With simulated annealing, the selection of moves depends on an annealing schedule that would allow the organization to select some bad moves, so that it does not get stuck in local optima.

This work using OrgAhead is based on a great deal of prior research using OrgAhead to examine turnover related issues. Previous results indicate that criticality depends on how the organization is organized and, in particular, the way in which people are coordinated and the way in which information is distributed. This work indicated that metrics based on who knows who and who knows what are good indicators of criticality. In particular, metrics such as centrality, access to information, task exclusivity, knowledge exclusivity, and cognitive demand are valuable metrics.

Activities. In order to work with the decision-making experiment, we have extended the OrgAhead multi-agent network model to enable the system to capture individual agents' performance and confidence in decisions. We have also expanded the system to enable newcomers to enter at predefined times and in pre-defined locations. We added a GUI user interface and altered the data reporting structure to generate data appropriate for ORA and in CSV files. We conducted a number of virtual experiments and tuned the system to replicate various lab and field data.

Our simulation research using OrgAhead has obtained evidence that (a) turnover, team structure, and member training interact (e.g., turnover has a particularly detrimental effect when team structure is highly collaborative and members are trained to follow their experience as opposed to standard operating procedures) and (b) more hierarchical organizations are better able to absorb poorly trained newcomers.

A second set of virtual experiments looked at the relative impact of turnover. Here we found that if teams evolved naturally (i.e., newcomers were not forced into particular positions), when one agent leaves another who is most structurally equivalent will move to take his/her place with little impact on performance. When newcomers enter strategically (i.e., they are added in pre-defined locations), how acceptable they are to the team depends on the hamming distance between the team with the newcomer and the team without. Here, the hamming distance is the number of links in the meta-matrix that are different if a replaces b (i.e., how close the topological patterns are). Further, in this case, the new person is more likely to be accepted if he/she is more similar to the person who left.

Potential applications. Personnel rotation is a fact of life in the Army and can have several consequences. For example, when membership change is planned and new personnel are well trained, turnover may have minimal effects on team performance. In contrast, when membership change is unplanned and/or new personnel are not prepared for their mission, turnover may severely degrade team performance. Finally, when team performance is already low (e.g., because well-learned task routines are not suited to a new operational environment), turnover may significantly enhance team performance. Our work suggests several strategies for reducing the costs and enhancing the benefits of membership change in teams. For example, our research on transactive memory systems suggests that warning teams that turnover will occur, combined with information about a newcomer's skills, partially mitigates the negative consequences of turnover. Our work on newcomer innovation suggests that the more similar newcomers are to the people they replaced, the less disruptive they are to the team structure and the higher their acceptance. However, we also note that it may be that the more similar the newcomers are to the people they replace, the less likely they are to be innovative. Future work needs to explore the tradeoff between acceptance and innovativeness.

Available Tools and Future Directions

As noted, for this contract we developed user interfaces to Construct and OrgAhead. This facilitated their use by people other than members of the CASOS lab. Both tools have been requested and sent to DSTO Australia and to multiple companies. Construct has also been briefed to several firms that consult regularly with the military and to various intelligence agencies.

Tested versions of both Construct and OrgAhead are available on the CASOS web site (Construct: http://casos/projects/construct/OrgAhead: http://casos/projects/OrgAhead/). There are approximately 1-2 downloads a week for each tool. In addition, both Construct and OrgAhead are taught in the CASOS summer institute, and various short courses on each have been taught at various agencies.

Finally, many of the measures developed for critical personnel under this project are now being used to evaluate groups in the Army Battle Lab experiments as part of the C2Net technologies. Current discussions are underway with SA technologies about continuing that work as part of a cross-consortia between the Advanced Decisions Architectures and the Networks & Sensors group. Finally, CMU (the DDML and CASOS group) have been invited to use the Joint Forces Command's (JFCOM) Joint Forces Personnel Recovery Agency (JPRA) (http://www.jfcom.mil/about/com_jpra.htm) school house as a venue for conducting Dynamic Social Network Analysis & Modeling. JPRA is located in Fredricksburg/Ft Belvoir VA. We will be teamed with SA technologies for all work (http://www.satechnologies.com/html/overview.html) and are currently looking for funding for that project. Currently we are looking for a venue to combine ORA (the measurement engine) with Construct with streaming data to provide a tool to the commander for unit evaluation. We are also exploring how the measures of criticality relate to situation awareness and so unit adaptability.

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